SPECIFICATION

TITLE OF THE INVENTION

LIQUID COOLING SYSTEM AND PERSONAL COMPUTER USING THEREOF

BACKGROUND OF THE INVENTION

The present invention relates to a liquid cooling system for cooling body generating heat therefrom, and in particular, to such a liquid cooling system being suitable for the structure of being small and/or thin in sizes thereof.

Semiconductor devices, being used in electronic apparatuses, such as a computer, etc., generate heat thereby when it operates. In particular, high-integrated semiconductor devices in recent years increase an amount of the heat generating thereby. Since the semiconductor device looses the function thereof if temperature thereof exceeds a certain value, cooling is necessary for such the semiconductor device having a large amount of heat generation therewith.

For a method for cooling the semiconductor device of an electronic apparatus, there are known various manners, such as of adopting thermal conduction or air-cooling, or using a heat pipe, or by means of liquid cooling.

Cooling of adopting the thermal conduction can be achieved by applying materials having large thermal conductivity on a route

of heat radiating, reaching from the semiconductor device to an outside of the electronic apparatus. This method is suitable for so-called a compact electronic apparatus, in which heat generation is relatively small, such as a notebook-type personal computer.

With the cooling by using air, an air blower or fan is provided inside the electronic apparatus, thereby achieving the cooling of the semiconductor device therein through compulsively circulating air thereon. This method is adopted widely for cooling of the semiconductor device having a certain amount of heat generation, and it was also applied to the personal computer by making the air blower small and thin in the sizes thereof.

Cooling with using the heat pipe, in which heat is carried out to an outside of the electronic apparatus by means of coolant enclosed within a pipe, was described in Japanese Patent Laying-Open No. Hei 1-184699 (1989), and Japanese Patent Laying-Open No. Hei 2-244748 (1989), for example. With this method, since there is provided no part of consuming electric power therein, such as the air blower or fan, therefore it has good efficiency, i.e., increases the cooling of the thermal conduction further. However, with this method, there is a limit in an amount of heat that can be transferred therewith.

The cooling by means of liquid coolant is suitable for the cooling of the semiconductor device having a large amount of heat generation, and it was described, for example, in Japanese Patent Laying-Open No. Hei 5-1335454 (1993), Japanese Patent Laying-Open No. Hei 6-97338 (1994), Japanese Patent Laying-Open No. Hei 6-125188 (1994), and Japanese Patent Laying-Open No. Hei 10-213370 (1998), for example. However, such the cooling system of liquid is restricted in the field of utilization thereof, such as a large-scale computer. This is, because the cooling system of liquid necessitates a large number of parts, such as a pump, pipe system, heat radiation fin, etc., being exclusive use for the cooling, the apparatus comes to be large in sizes, and it is difficult to

maintain reliability of using the liquid for cooling comparing to other methods. It is also one of reasons, the fact that no such the semiconductor device requiring such the cooling by means of liquid is used other than a field of the large-scale computer.

A technology of adopting the liquid cooling into a small-sized apparatus, including such the notebook-sized personal computer, is described in Japanese Patent Laying-Open No. Hei 6-266474 (1994). In this prior art, a header attached onto the semiconductor device and a heat radiation pipe separately located from it are connected with each other by means of a flexible tube, wherein heat is transferred through the liquid flowing therein, thereby obtaining the cooling thereof.

However, an amount increases up remarkably of heat generation from the semiconductor devices, which are used in the electronic devices, such as a personal computer, a sever computer, a work station, etc., in recent years, then only adoption of such the conventional art is not sufficient for applying it into the electronic apparatuses, being required to be small and thin in sizes much more, in particular, such as the notebook-type personal computer.

SUMMARY OF THE INVENTION

An object of the present invention, therefore, is to provide a liquid cooling system being able to cool down high heat generated by a heat generating body, such as, the semiconductor device or element, which is used in such the electronic apparatus of being small and thin in sizes thereof, and also to provide a personal computer equipped with such the structure therein.

Such the object as mentioned above, according to the present invention, is accomplished by the construction of a liquid cooling system of superior efficiency, being small and thin in sizes, or a personal computer equipped with such the liquid cooling system,

being peculiar to such the personal computer, which is small and thin in the sizes thereof.

A pump is necessary for promotion of circulation of liquid in the liquid cooling system, however with a pump of rotational type, which is usually applied to, it is impossible to realize, in particular, in viewpoints of such ultra-small and thin sizing, and the low electric power consumption, as well. For this reason, it is effective to apply a pump of pressurizing the liquid through reciprocal movement of a member. However, even when using such the pump of reciprocal type, it is necessary to satisfy the following conditions, for the purpose of constructing a system of low electric power consumption, enabling cooling effectively.

In more details, according to the present invention, there is provided a liquid cooling system, comprising: a pump for supplying cooling liquid in a form of pulsation; a heat receiving jacket being supplied with said cooling liquid, and for receiving heat generated from a heat generating body; a heat radiation pipe for radiating heat which is supplied by the cooling liquid passing through said heat receiving jacket; and a passage for circulating the cooling liquid passing through said heat radiation pipe into said pump, wherein said cooling liquid circulates within a closed flow passage, and further ΔVs is equal to or greater than ΔVp, assuming that inner volume change when said pump emits the pulsation therefrom is the ΔVp, that pressure caused accompanying with said volume change is P, and that volume change due to said pressure P in the flow passage of the cooling liquid ΔVp other than portion of said pump.

Further, for an example, said pump emits the pulsation by the reciprocal movement of the member within the pump, and the reciprocal movement of the member of said pump is caused by bending or flexure of the diaphragm. This diaphragm itself or a driving source of the diaphragm is preferably formed with a piezo element,

from viewpoints of small-sizing, low electric power consumption and low noises, etc. With this, it is possible to maintain a carrying amount of the cooling liquid, even in the computer being small and thin in sizes, thereby to obtain effective cooling.

Also, a rubber pipe or a resin pipe may be used in at least a portion of the connector pipe, constructing the flow passage for carrying said cooling liquid therein, and further the surface of said resin or rubber pipe is coated with a metal film or a resin sheet covered with a metal film, thereby suppressing diffusion of the cooling liquid through the rubber and the resin into the atmosphere, and enabling conduction of heat with efficiency, as well.

The liquid cooling system defined in the above, preferably, further comprises an accumulator, in which the volume change of the cooling liquid owned by itself due to said pressure P is equal or greater than the ΔVp, from a viewpoint of management of pressure.

Further, the accumulator has such the structure that it retains the cooling liquid therein and is able to change the retaining amount thereof. For example, it may be a such one that it changes the retaining amount by deformation of itself. Or alternatively, it may be in such the structure that it keeps gas further within an inside thereof.

The accumulator mentioned above may be made of contractual material, such as rubber or resin, for example, thereby being movable due to the change in the pressure. Or, it may be constructed by utilizing the construction of metal bellows. Or, it may adopt a piston mechanism thereto.

Further, in the liquid cooling system of the above, it is preferable that said cooling liquid is pressurized at pressure being equal to or higher than that of an atmosphere.

Also, in the liquid cooling system of the above, said accumulator comprises a supply opening for supplying said circulating cooling liquid therethrough and a discharge opening for discharging said cooling liquid therethrough, and it maintains gas and said cooling liquid therein. It is preferable for said accumulator to be disposed in series with the heat receiving jacket or/and the heat radiation pipe.

Further, as a personal computer having such the liquid cooling system, according to the present invention, there is provided a personal computer, comprising: a semiconductor element; a signal input portion; a display device; and a liquid cooling system, including: a pump for supplying cooling liquid in a form of pulsation; a heat receiving jacket being supplied with said cooling liquid, and for receiving heat generated within said semiconductor element; a heat radiation pipe for radiating heat which is supplied by the cooling liquid passing through said heat receiving jacket; and a passage for circulating the cooling liquid passing through said heat radiation pipe into said pump, wherein said cooling liquid circulates within a closed flow passage, and further ΔVs is equal to or greater than ΔVp, assuming that inner volume change when said pump emits the pulsation therefrom is the ΔVp, that pressure caused accompanying with said volume change is P, and that volume change due to said pressure P in the flow passage of the cooling liquid ΔVp other than portion of said pump.

Furthermore, as a notebook-type personal computer, there is provided a personal computer, comprising: a main body including a semiconductor element and a signal input portion; a display device having a display portion, being connected with said main body through a movable mechanism; and a liquid cooling system, including: a pump for supplying cooling liquid in a form of pulsation; a heat receiving jacket being disposed within said main body and supplied with said cooling liquid, and for receiving heat generated within said semiconductor element; a heat radiation pipe

being disposed in a back surface of said display portion of said display device, and for radiating heat which is supplied by the cooling liquid passing through said heat receiving jacket; and a passage for circulating the cooling liquid passing through said heat radiation pipe into said pump, wherein said cooling liquid circulates within a closed flow passage, and said display device comprises an accumulator comprises: a supply opening for supplying said circulating cooling liquid therethrough; and a discharge opening for discharging said cooling liquid therethrough, and maintains gas and said cooling liquid therein, wherein, an amount of the cooling liquid maintained within said accumulator is changed responding to emission of the pulsation from said pump.

Moreover, as a detailed embodiment according to the present invention, there is provided a personal computer, comprising: a semiconductor element; a signal input portion; a display device; and a liquid cooling system, including: an emission pump for supplying cooling liquid in a form of pulsation by using reciprocating movement of a diaphragm having a piezo element; a heat receiving jacket being supplied with said cooling liquid, and for receiving heat generated within said semiconductor element; a heat radiation pipe for radiating heat which is supplied by the cooling liquid passing through said heat receiving jacket; an accumulator comprising, a supply opening for supplying said circulating cooling liquid therethrough and a discharge opening for discharging said cooling liquid therethrough, and for maintaining gas and said cooling liquid therein; and a passage for circulating the cooling liquid passing through said heat radiation pipe into said pump, wherein said cooling liquid circulates within a closed flow passage, and said display device comprises wherein, said cooling liquid circulates within a closed flow passage, and, an amount of the cooling liquid maintained within said accumulator is changed responding to emission of the pulsation from said pump.

Next, explanation will be given by referring to Fig. 13.

The flow passage in the liquid cooling system according to the present invention will be shown in the Fig. 13. The flow passage is constructed with a pump 1 and connector pipes 3, and cooling liquid is filled up within an inside thereof. The connector pipe 3 is connected to both an outlet and an inlet of the pump, thereby forming a closed loop. The pump 1 is constructed with a diaphragm 8 performing reciprocal movement and check valves 9a and 9b, and a case. Now, considering a case where the diaphragm comes to the position of a solid line, since the cooling liquid within the pump is pressurized, then the check valve 9b is opened. Repeating this operation, continuingly, the pulsation is emitted from the pump, thereby to circulate the cooling liquid within the route thereof. In this instance, for the cooling liquid to move in the direction of arrows, it is necessary that a portion or the entire connector pipe 3 be expanded, so that the cooling liquid within the pump flows into that direction.

Fig. 14 shows a relationship between flow rate Q of the pump and the pressure P. Herein, Pmax indicates the maximum pressure that is generated or developed when the exit of the pump is closed so that no cooling liquid flows therethrough, and Qmax the maximum flow rate when the exit of the pump is opened, so as to remove the pressure loss away therefrom. In this graph, the relationship between the flow rate Q and the pressure P can be determined, and then the flow rate comes to be Q_0 when a pipe of pressure loss P_0 is connected, for example.

In the liquid cooling system according to the present invention, since the cooling liquid is circulated within the flow passage with the pulsation thereof, by applying such the reciprocating pump therein, the volume change ΔVp due to supply of the pulsation (i.e., due to the reciprocating movement) can be obtained from Q/(number of vibration f), therefore the relationship between the volume change ΔVp and the pressure P can be drawn as shown in Fig. 15. Also, since the pressure P applied

on the pipe and the volume change ΔVs are proportional to each other, the relationship comes to be indicated by a straight line (1), for example. In this instance, at a point where the straight line (1) and the characteristic curve of the pump come across, pressure P_1 and volume change ΔV_1 can be determined. In a case of forming an open loop, the volume change is determined by the pressure loss P_0 of the pipe, thereby obtaining the volume change ΔV_0, however if using a rigid or hard pipe having small volume change therein, as indicated by (1), only the volume change of ΔV_1 can be obtained, being smaller than the ΔV_0. Accordingly, the flow rate comes down, and then the cooling performance also comes down. On the contrary to this, in a case where the volume change with respect to the pressure is large, as is indicated by (1), namely, in the case of using a soft pipe, since the volume change ΔV_0 come to be large at the crossing point of the straight line (2) with the characteristic curve of the pump, the primary volume change can be obtained at the ΔV_0, therefore it is possible to show up sufficient characteristics. Thus, if defining that the volume change due to the reciprocal movement of the pump member is ΔVp, pressure caused when occurring the volume change ΔVp is P, volume change of the expansible portion 10 when the pressure P is applied thereon is ΔVs, it is possible to draw out the characteristics of the liquid cooling system at high efficiency, by making ΔVs larger than ΔVp, therefore it is possible to construct the system of low electric power consumption therein.

Also, in a liquid cooling system comprising two (2) pumps for pressurizing the liquid by means of the reciprocal movement of members, the heat receiving jacket having function of heat exchanger for cooling the heat generating body, the heat radiation pipe for conducting heat exchange with an outside air, and the connector pipe for connecting those parts mentioned above, wherein the two (2) pumps, the heat receiving jacket and the heat radiation pipe are disposed in a closed loop by means of the connector pipe,

and the cooling liquid is filled up within the two (2) pumps, the heat receiving jacket, the heat radiation pipe, and the connector pipe, therefore the same effect can be obtained with shifting by 180 degree, in the phase of reciprocal movements of the members of the pumps provided in the number of two (2), therefore it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

Those and other features, objects and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings wherein:

Fig. 1 shows a perspective view of a notebook-type personal computer utilizing the liquid cooling system, according to an embodiment of the present invention;

Fig. 2 shows a view of the liquid cooling system, according to an embodiment of the present invention;

Fig. 3 shows a view of the liquid cooling system, according to other embodiment of the present invention;

Fig. 4 shows a view of other liquid cooling system, according to an embodiment of the present invention;

Fig. 5 shows a view of the liquid cooling system, according to further other embodiment of the present invention;

Fig. 6 shows a view of other liquid cooling system, according to the further embodiment of the present invention;

Fig. 7 shows a view of the liquid cooling system, according

to further other embodiment of the present invention;

Fig. 8 shows a view of the liquid cooling system, according to further other embodiment of the present invention;

Fig. 9 shows a view of the liquid cooling system, according to further other embodiment of the present invention;

Fig. 10 shows a cross-sectional view of a connection pipe used in any embodiment of the present invention;

Fig. 11 also shows a cross-sectional view of a connection pipe used in any embodiment of the present invention;

Fig. 12 shows a view of the liquid cooling system, according to further other embodiment of the present invention;

Fig. 13 shows a principle of the liquid cooling system for explanation about basic law of the present invention;

Fig. 14 shows a graph for showing a relationship between flow rate and pressure of a pump which is used in the liquid cooling system, according to the embodiment of the present invention; and

Fig. 15 shows a graph for showing a relationship between volume change and pressure of the pump which is used in the liquid cooling system, according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, embodiments according to the present invention will be fully explained by referring to the attached drawings.

Fig. 1 shows a notebook-type personal computer using the liquid cooling system according to the present invention. To a

semiconductor element or device 5 installed within a main body chassis or housing 6 is connected a heat receiving jacket 2, in which a flow passage is provided. In the a main body chassis 6 is also provided a pump 1. Behind a display panel of a display device chassis 7 is provided a heat radiation pipe 4. The pump 1, the heat receiving jacket 2, the heat radiation pipe 4 are connected with a connector pipe 3 in a closed loop-like manner, as shown in the figure, and in an inside of them is filled up with a cooling liquid.

Fig. 2 shows a first embodiment of the cooling system of the notebook-type personal computer shown in the Fig. 1, diagrammatically. The pump 1, the heat receiving jacket which is connected onto the semiconductor element 5 mounted on a print board 11, and the heat radiation pipe 4 are connected with, by means of the connector popes 3. The pump 1 is constructed with a diaphragm conducting reciprocal movement therein and check valves 9a and 9b, as well as a case. A portion of the connector pipe 3 is made of a soft material, so as to form an expansible portion 10 therewith. When the diaphragm 8 comes to the position shown in the figure, the cooling liquid is suppressed, and then the check valve 9b is opened. Then, due to the pressure of the cooling liquid, the expansible portion 10 is expanded, therefore the cooling liquid moves in a direction of an arrow. Next, when the diaphragm comes back to the position of broken line, since the pressure falls down, the check valve 9a is opened, and the cooling liquid within the connector pipe flows into an inside of the pump while the expansible portion 10 turns back to the original position indicated by broken line. Repeating of this operation makes the cooling liquid circulating in the flow passage. The cooling liquid wormed up in the heat receiving jacket 2 is cooled down in the heat radiation pipe 4, and it flows into the heat receiving jacket again via the pump 1. Repeating this makes possible effective cooling, even of the semiconductor element having a large amount of heat generation therefrom. (In particular, it is effective when it is applied into a personal computer having a semiconductor element, which emits

heat generation over 30W.)

According to the present embodiment, if defining that the volume change due to the reciprocal movement of the pump member is ΔVp, pressure caused when occurring the volume change ΔVp is P, volume change of the expansible portion 10 when the pressure P is applied thereon is ΔVs, then ΔVs is larger than ΔVp. Because of this, as was mentioned in the "Summary of the Invention", it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption.

Measurement of values of those mentioned above can be performed by the following manner, for example.

The connector pipe 3 for collecting the cooling liquid into the pump 1 is cut off just in front thereof. A pressure gauge is provided just below the pump 1 in downstream side of the pump 1. The cooling liquid is supplied from a source of cooling liquid to the pump 1, and then the pump 1 is driven. And then, the flow rate and the pressure "P0" are measured. Next, an amount of the volume change (ΔVp) mentioned above is obtained as the flow rate per one (1) revolution, from the frequency of pulsation (i.e., the reciprocal movement of an inner member) of the pump 1.

Next, the connector pipe, being cut off, is hermetically sealed at an end of the side opposing to the pump 1, and the personal computer and so on are positioned so that the flow passage of the cooling liquid comes to be in as horizontal as possible. And then, a column of water is connected to the connector pipe, which is cut off, at the side of the pump, so as to measure the volume change ΔVs and the pressure P1 in the flow passages of cooling water other than the pump, through change in height of the water column and/or height thereof. On a P-V graph, Vs and P1 are plotted, and a straight line is drawn from the origin. In case of comparing the straight

line with the plotted points of P0 and ΔVp, the P0 has a larger value when comparing the both pressures on the ΔVp.

Further, the connector pipe 3 is made soften in a portion thereof in the present embodiment, thereby to obtaining a function of bringing the ΔVs to be equal or greater than ΔVp, however it may be soften as a whole, so as to achieve the function of bringing the ΔVs to be equal or greater than ΔVp. Also, such a material can be listed, as a material of the connector, for example, rubber of low rigidity or resin.

Fig. 3 shows the liquid cooling system according to a second embodiment of the present invention, diagrammatically. The structure of the system is almost equal to that of the first embodiment, however in the place of the expansible portion 10 in the first embodiment, an accumulator 12 is attached, which is filled up with the cooling liquid therein. In this figure, also solid lines and broken lines of the diaphragm 8 correspond to those of the accumulator 12. When the pump 1 is compressed within an inside thereof by means of the diaphragm 8, the check valve 9b is opened, and then the pressure is transferred to the accumulator 12, therefore it is expanded as shown by the solid lines. Due to this expansion, the cooling liquid can flow in the direction of arrows. In the present embodiment, the volume change of the accumulator 12 is ΔVs, which is caused when the pressure P is applied thereon, and the ΔVs is equal or greater than the ΔVp. Therefore, it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption.

In the present embodiment, though the accumulator 12 is attached to the connector pipe 3 branching off therefrom, however the accumulator 13 may be connected to the connector pipe 3 in series, as shown in Fig. 4, so as to insert it into a closed loop, thereby obtaining the same effect, as far as the ΔVs is equal or

greater than the ΔVp.

Also, in a case where the accumulator 12 or 13 has the structure of changeable, i.e., becomes large or small in sizes, as a material of the accumulator 12 or 13, rubber of low rigidity or resin can be listed up, for example. On a while, in the place thereof, such the structure also can be considered that a gas portion (for example, air, etc.) and a delay portion for the cooling liquid are provided within an inside of the accumulator. The accumulator 12 or 13 may be provided with a supply opening for supplying the cooling liquid therethrough, and an exit opening (not shown in the figure) for discharging the cooling liquid standing in the accumulator 12 or 13.

Further, though the accumulator is disposed on the route between the pump 1 and the heat receiving jacket 2 in the present embodiment, however, more preferably from a viewpoint of effective small-sizing thereof, etc., within the display device chassis 7 in the Fig. 1, as well as, on the route between the pump 1 and the heat receiving jacket 2. More preferably, it may be positioned in a downstream side of a region where the heat radiation pipe 4 is disposed, from a viewpoint of protection from corrosion, etc.

Fig. 5 shows the liquid cooling system according to a third embodiment of the present invention, diagrammatically. The structure of the system is almost equal to that of the second embodiment shown in the Fig. 3, however a metal bellows 14 is attached to as the accumulator. Also in this figure, solid lines and broken lines of the diaphragm 8 correspond to those of the metal bellows 14. When the pump 1 is compressed within an inside thereof by means of the diaphragm 8, the check valve 9b is opened, and then the pressure is transferred to the metal bellows 14, therefore it is expanded as shown by the solid lines. With this expansion, the cooling liquid can flow in the direction of arrows. In the present embodiment, the volume change of the metal bellows 14is ΔVs, being

caused when the pressure P is applied thereupon, and the ΔVs is equal or greater than the ΔVp. Therefore, it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption.

Furthermore, in the present embodiment, though the metal bellows 14 is attached to the connector pipe 3 branching off therefrom, however the metal bellows 14 may be connected to the connector pipe 3 in series, as shown in Fig. 6, so as to insert it into a closed loop, thereby obtaining the same effect, as far as the ΔVs is equal or greater than the ΔVp. And, for example, stainless steel and phosphor bronze can be listed up, as the material of the metal bellows 14.

Fig. 7 shows the liquid cooling system according to a fifth embodiment of the present invention, diagrammatically. The structure of the system is almost equal to that of the second or third embodiment, however a piston mechanism 16 is applied as the accumulator. The piston mechanism 16 has such the structure as an injector or syringe, and it is pushed up at one end thereof by means of a spring. When the pump 1 is compressed within an inside thereof by means of the diaphragm 8, the check valve 9b is opened, and then the pressure is transferred to the piston mechanism 16, therefore the piston is shifted upward in the Fig. 7. With this shifting, the cooling liquid can flows in the direction of arrows. In the present embodiment, the volume change of the piston mechanism 16 is ΔVs, being caused when the pressure P is applied thereupon, and the ΔVs is equal or greater than the ΔVp through adjusting strength of the spring adequately. Therefore, it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption. As the material of the piston mechanism 16, metal, resin and glass can be listed up, however it is also possible to use the injector or syringe available on the market.

As the spring used in the piston mechanism 16, there can be listed up, for example, a plate spring, an air spring, etc., other than the coil spring shown in the Fig. 7.

Fig. 8 shows the liquid cooling system according to a fifth embodiment of the present invention, diagrammatically. The structure of the system is almost equal to that of the second embodiment, however the cooling liquid is filled up with pressure. In this figure, also solid lines and broken lines of the diaphragm 8 correspond to those of an accumulator 17. Also, an original shape (a shape of no difference in pressure between outside and inside thereof) of the accumulator 17 is shown by one-chained dotted lines. Since the cooling liquid is filled up with pressure, the shape of the accumulator 17 is larger than the original one even when the diaphragm 8 of the pump 1 comes to the position shown by broken lines. Even if the cooling liquid is pressurized to be filled up, it is possible to obtain the same effect to that of the first embodiment, if the volume change ΔVs of the accumulator 17, being caused when the pressure P is applied thereupon, is equal or greater than the ΔVp, therefore it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption.

As a distinctive effect according to the present embodiment, it is possible to point out that the cooling liquid can be protected from bubbles generated from a long-time use thereof in the system. Using of rubber or resin, as the material of the connector 3 or the accumulator 17, causes diffusion of molecular of the cooling liquid therein, though being a very small amount, thereby it sneaks away into an atmosphere. If the pressure within the system is lower than the atmospheric pressure, the air diffuses into the rubber or resin, to sneak into the flow passage, therefore, there is a possibility of generating the bubbles therein. The bubbles may disturb or obstruct the operation of the check valve, therefore,

it is important for the present system to prevent from them.

Further, it is needless to say that the effect, being completely same to that of the present embodiment, can be obtained by filling up the cooling liquid with pressure, even in the first, the third and the forth embodiments.

Fig. 9 shows the liquid cooling system according to a sixth embodiment of the present invention, diagrammatically. The structure of the system is almost equal to that of the first embodiment, however soft rubber or resin is used as the material of the connector pipe 3, in the present embodiment. And, surface of the connector pipe 3 is covered or coated with metal film 18 around it, as shown in Fig. 10. As the distinctive effect of the present embodiment can be listed up that, since the connector pipe 3 is made of the soft material, other parts, such as the pump, the heat receiving jacket, the heat radiation pipe, etc., can be positioned freely. Also, it is possible to fold a portion of the heat radiation route repetitively. However, if using the rubber or resin, the molecular of cooling liquid diffuses therein, as was explained in the fifth embodiment, therefore it may sneak away into the atmosphere. According to the present embodiment, since the surface of the connector pipe 3 is covered with the metal film 18, it is possible to prevent the cooling liquid from reduction thereof. Also, as shown in Fig. 11, the same effect can be obtained by covering the connector pipe with a resin sheet 19, including a metal films 19a and a resin film 19b. In this case, it does not matter if there is defined space between the resin sheet 19 and the connector pipe 3, however they must be closely adhered to each other at both ends thereof.

Fig. 12 shows the liquid cooling system according to a seventh embodiment of the present invention, diagrammatically. In the present embodiment, two (2) pumps are provided in series, thereby forming a flow passage of closed loop. Solid lines and broken lines of the diaphragms 8 and 8′ correspond to each other. When the

diaphragm 9 of the pump 1 leis at the position of the solid line, so as to pressurize the cooling liquid therewith, the diaphragm 8' of the pump 1' lies in the position of the solid line, therefore the cooling liquid emitted from the pump 1 flows into the pump 1'. In this manner, since the two (2) of the pumps are shifted by 180 degree in the phase of reciprocal movements of the diaphragms thereof, the cooling liquid can flow in the direction of arrows, therefore obtaining the effects being totally same to those of the other embodiments, i.e., it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, thereby to construct a system of low electric power consumption.

Furthermore, in the present embodiment, there is no need of providing such an expansible portion in the flow passage, like the other embodiments, however it does not matter to apply it in common with that of the other embodiments.

However, since two (2) of the pumps are used in the present embodiment, the pressure of compression comes to be large, thereby increasing the flow rate, therefore it has a distinctive effect that the cooling effect can be improved more than those of the other embodiments.

As was mentioned in the above, according to the present embodiment, since it is possible to draw out the characteristics or performances of the liquid cooling system with high efficiency, therefore it is possible to provide the liquid cooling system of ultra-small and thin in sizes, as well as of low electric power consumption, and further it enable to install such the semiconductor element of generating high temperature therefrom into the personal computer, by applying the present system therein.

According to the present invention, as was fully explained in the above, it is possible to provide a liquid cooling system with low electric power consumption, being able to cool down a

body generating high heat therefrom, such as the semiconductor element used in the electronic apparatus being small-sized and thin, or to provide a personal computer equipped with such the structure.

While we have shown and described several embodiments in accordance with our invention, it should be understood that the disclosed embodiments are susceptible of changes and modifications without departing from the scope of the invention. Therefore, we do not intend to be bound by the details shown and described herein but intend to cover all such changes and modifications falling within the ambit of the appended claims.